

THE REDISCOVERY AND STATUS OF *DISSANTHELIUM CALIFORNICUM*
(POACEAE) ON SANTA CATALINA ISLAND, CALIFORNIA

JENNY L. MCCUNE AND DENISE A. KNAPP¹

Catalina Island Conservancy, Conservation Department, P.O. Box 2739, Avalon, CA 90704

ABSTRACT

Dissanthelium californicum (Nutt.) Benth. (Poaceae) is an annual grass known only from Santa Catalina and San Clemente Islands, off the coast of Southern California, USA, and Guadalupe Island, off the coast of Baja California, Mexico. It had not been recorded since Blanche Trask collected it in 1903 on San Clemente Island, and was therefore considered to be extinct, possibly as a result of overgrazing by introduced goats on these islands. During monitoring by the Catalina Island Conservancy from March through July 2005, *D. californicum* was discovered growing in seven diverse and widely spread locations on Santa Catalina Island. The rediscovery may be a result of the removal of feral goats and pigs from the island, record-breaking rainfall, and increased exploration of remote areas. A revised description of the species and a summary of its habitat preferences are provided. Thorough monitoring and surveying of known and potential locations will be necessary to better determine the conservation status of the species.

RESUMEN

Dissanthelium californicum (Nutt.) Benth. (Poaceae) es una gramínea anual conocida sólo de las islas Santa Catalina y San Clemente, que se encuentran cerca de la costa del Sur de California, USA y de la isla Guadalupe, localizada cerca de la costa de Baja California, México. Esta especie no ha sido reportada desde que Blanche Trask la colectó en 1903 en la isla San Clemente, y por lo tanto ha sido considerada como extinta, posiblemente como resultado del sobre pastoreo de cabras introducidas a las islas. Durante el monitoreo realizado por la organización Catalina Island Conservancy en los meses de marzo a julio del 2005, *D. californicum* fue redescubierto creciendo en siete diversas y muy distantes localidades de la isla Santa Catalina. El redescubrimiento podría haberse dado debido a la eliminación de las cabras y cerdos de la isla, a la lluvia sin precedentes y el aumento de exploración en áreas remotas. Una descripción revisada de la especie y un resumen de su preferencia en hábitat son proporcionadas. Riguroso monitoreo e inspección de localidades conocidas y potenciales serán necesarios para una mejor determinación del estado de conservación de la especie.

Key Words: California, *Dissanthelium*, extinct, Guadalupe Island, Poaceae, rediscovery, San Clemente Island, Santa Catalina Island.

Dissanthelium californicum, an annual grass first collected and described in the mid-1800s, is known from three islands off the coast of southern California and Baja California, Mexico. Last collected in 1903 and subject to severe grazing pressures on all three islands, it had been presumed extinct until its re-discovery in 2005 on Santa Catalina Island (hereafter Catalina Island). In this paper, the history of this species is discussed and new population information is presented, including a revised description. Current conservation actions and concerns are discussed.

TAXONOMIC AND COLLECTION HISTORY

Thomas Nuttall, in his presentation to the Academy of Natural Sciences in 1848, described over one hundred plant species collected in the American West (Jercinovic 2004). Among the

species was an annual grass that had not yet been described, collected by William Gambel on Catalina Island, off the southern coast of California. Nuttall placed the annual grass in a new genus named *Stenochloa*, and gave it the specific epithet *californica* (Nuttall 1848). Bentham later transferred it to the genus *Dissanthelium*, giving it the specific epithet *californicum* (Hooker 1881).

The genus *Dissanthelium* was described by C.B. Trinius in 1836, and comprises approximately 20 species (Nicora 1973; Swallen and Tovar 1965; Tovar 1985; Soreng 1998; Soreng et al. 2003). Most species grow at high altitudes, usually ~4000–5000 m, in the central Andes; one of these species also grows on the high volcanoes of central Mexico (Swallen and Tovar 1965; Tovar 1985). *Dissanthelium californicum* is the only species in the genus found north of the equator at elevations near sea level. A recent phylogenetics study by Refulio-Rodriguez has determined that *Dissanthelium* forms a clade nested within the genus *Poa* (Refulio-Rodriguez 2007).

¹ Author for correspondence, e-mail: dknapp@lifesci.ucsb.edu

The placement of *D. californicum* in the genus was questioned by Hitchcock (1923), who wrote that "this species does not appear to be closely related to the other two [(Andean) species, the only ones recognized at the time], but it does not seem to be sufficiently different to constitute a distinct genus." Oscar Tovar, an authority on the genus, has also questioned the position of *D. californicum* in the genus (personal communication). Unfortunately, low DNA sequence variation within the *Dissanthelium* clade prevents a full analysis of the relationships among its species (Refulio-Rodriguez 2007).

Dissanthelium californicum was collected only twice more following Gambel's collection; in 1875 by Edward Palmer on Guadalupe Island, 261 km off the coast of Baja California, Mexico (Moran 1996), and in 1903 by Blanche Trask on San Clemente Island, about 34 km south of Catalina Island (Jepson 1912; Raven 1963).

There has been some uncertainty about the dates of the collections made by Gambel and Trask. The isotype of *D. californicum* and other specimens collected by Gambel deposited in the Gray (GH23589, isotype) and Kew herbaria (Phillips personal communication) lack a date of collection. According to Millspaugh and Nuttall (1923), Gambel visited Catalina Island in February 1847. Elsewhere, however, Gambel is reported to have arrived in California in November 1841 (McKelvey 1955; Graustein 1967), and visited Catalina Island in 1842 (McKelvey 1955). He remained on the West Coast until 1845, when he returned to Philadelphia in order to enter medical school (Jercinovic 2004). He had sent his plant specimens by whaling ship, which did not arrive until nearly a year after he had returned. From Philadelphia, he sent the collection to Nuttall in England for identification, which explains the delay between Gambel's collection and Nuttall's paper (Graustein 1967; Jercinovic 2004). Thus *D. californicum* was first collected between 1841 and 1845.

In Smith's treatment of *D. californicum* in *The Jepson Manual: Higher Plants of California*, the last known collection of the species, taken by Trask, is said to be 1912 (Smith 1993). However, Raven (1963) does not mention any trips by Trask to San Clemente after 1903. We examined one of Trask's specimens (*Trask* 324, PH 469621), and the year 1903 is penciled in on the label, along with the word "common." We could find no evidence that Trask or anyone else collected *D. californicum* after 1903, and conclude that the 1912 sighting reported by Smith (1993) is an error.

Dissanthelium californicum is known from Catalina and San Clemente Islands off the coast of California, USA, and Guadalupe Island off the coast of Baja California, Mexico (Millspaugh and Nuttall 1923; Raven 1963; Thorne 1967,

1969; Moran 1996; Ross et al. 1997). Both Eastwood (1941) and Dunkle (1950) list *D. californicum* as occurring on Santa Cruz and Santa Rosa Islands in addition to the three southern islands, while Dunkle (1950) adds a northern mainland distribution. However, extensive searches for herbarium specimens reveal that these reports are unsubstantiated (Wallace 1985; S. Junak, Santa Barbara Botanic Garden, personal communication).

Despite the fact that Catalina Island, San Clemente and Guadalupe Islands have been relatively well surveyed by botanists (e.g., Eastwood 1941; Millspaugh and Nuttall 1923; Moran 1996; Raven 1963; Thorne 1967, 1969), *D. californicum* has not been recorded since Trask's collection, and therefore, has been presumed extinct (e.g., CNPS 2001; Smith 1993). It has been suggested that intense herbivory by feral goats (*Capra hircus*) was the cause of *D. californicum*'s disappearance and the decline of other native plants growing on these islands (Thorne 1967; Moran 1996). Palmer, following work on Guadalupe, wrote that it was very succulent and that goats were very fond of it (Watson 1876). According to Moran (1996), "the plants were succumbing fast to the cresting goat population, and he [Palmer] was just in time to find eight natives never found on the island again: *Ceanothus cuneatus*, *Dissanthelium californicum*, *Hesperelaea palmeri*, *Micropus californicus*, *Planta* sp., *Pogogyne tenuiflora*, *Ribes sanguineum*, and *Silene antirrhina*."

REDISCOVERY

In the following description of our rediscovery of *D. californicum*, the term *population* refers to a distinct cluster of individual plants. An *occurrence*, as per the California Natural Diversity Database (Bittman 2001), consists of all populations found within 0.4 km of each other.

Biologists from the Catalina Island Conservancy (i.e., "the Conservancy") have been studying and monitoring plant communities on the island in an effort to learn how they are recovering from many years of overgrazing and how they may be further protected and restored. On March 29, 2005, during yearly monitoring of recently burned Island chaparral/coastal sage scrub habitat near Catalina Island's airport (the "Airport Burn"), a single individual of *D. californicum* was found growing within a large patch of *Malacothamnus fasciculatus* (Torrey & A. Gray) E. Greene (Occurrence 1, Figs. 1 and 2).

In the spring of 2005, we also began a project characterizing the *Quercus pacifica* Nixon & C.H.Mull. communities on the island, which brought us to many seldom-visited areas of the island. During these surveys in April, we discovered three additional populations of *D. californi-*



FIG. 1. Detail of the inflorescence fragment collected on first noticing *D. californicum* in Occurrence 1. Photo by Jenny L. McCune.

cum: one of approximately 60 plants on the eastern side of the island (Occurrence 2, Fig. 2), and two separated by about 80 m in the southwestern portion of the island, numbering 100 and 25 individuals (Occurrence 3, Fig. 2).

Upon hearing the news of our discovery, Nancy Refulio-Rodriguez, J. Travis Columbus, and Susan Jett (Rancho Santa Ana Botanic Garden, hereafter RSA), and Steve Junak (Santa Barbara Botanic Garden, hereafter SBBG) conducted a collecting trip to the island from May 2nd to 4th, 2005, during which additional plants, populations, and occurrences were discovered. At Occurrence 1, we counted approximately 140 plants in the vicinity of the first discovery (Fig. 2), within three populations. Columbus and colleagues also discovered a population about 500 m away (just outside of the burn area), consisting of approximately 70 individuals (Occurrence 4, Fig. 2). Additionally, we discovered 110 individuals in two new populations at Occurrence 2 and two more small populations at Occurrence 3, totaling 23 plants. Small amounts of seed were collected by the Conservancy (Accession numbers 1337–1340) and RSA (Accession numbers 21890–21894) to use for germination testing, storage, and restoration.

We collected voucher specimens from Occurrences 1–3 (McCune 1, 2 and 3 respectively), duplicates of which are deposited at the Wrigley Botanical Garden on Catalina Island, RSA, and SBBG respectively. Refulio-Rodriguez collected a voucher from Occurrence 4 (Refulio 238) and deposited it at RSA. Searches of Guadalupe and San Clemente Islands in 2005 did not reveal any *D. californicum* populations (Refulio-Rodriguez personal communication). A summary of all known herbarium specimens is presented in Table 1.

In mid-July, we found three additional occurrences within *Quercus pacifica* plots. The first consisted of four populations in the eastern section of the island near the town of Avalon, totaling 75 individuals (Occurrence 5, fig. 2). The second consisted of one population of four individuals, and the third consisted of one lone individual (Occurrences 6 & 7, Fig. 2); both occurrences are near the isthmus in the north-western section of the island. These finds brought the total to approximately 678 individuals in 17 populations and seven occurrences (Fig. 2).

Dissanthelium californicum occurred on a variety of aspects, elevations, and slopes and had a range of associated species (Table 2). The aspect of *D. californicum* locations ranged from northerly through easterly to south-southeasterly slopes, and in elevation ranged from approximately 137 m to 290 m. It was found predominantly in Island chaparral habitat, but also in areas where this habitat intergrades with coastal sage scrub.

REVISED DESCRIPTION

Dissanthelium californicum shows some plasticity in its characteristics. The plant height ranges from 10 cm or less to a maximum of 60 cm. In shade, it is usually a bright green, but in the open sun it tends to have a reddish tinge in the leaves, stems, and inflorescences. Each individual plant has from one to several flowering stalks. In general, the stalks were erect, but some, especially in shade, tended to be decumbent.

Dissanthelium californicum was flowering at the end of March when we first observed it, and by the beginning of May some seed was already mature. By mid- to late- May, most florets had fallen, and the plants discovered after May had turned tan in color with only empty glumes remaining. The new collections of this plant (along with inspection of previously existing collections) have given us an opportunity to produce a revised description, below.

Dissanthelium californicum (Nutt.) Benth. CALIFORNIA DISSANTHELIUM. Annual **Stem** 6–46 cm. **Leaf**: blade flat, 6–20 cm, 1–4 mm wide, smooth, ligule membranous. **Inflorescence** < 1.6 dm; panicle narrow to open, branches in fascicles, some of them floriferous to the base. **Spikelet** florets 2(3), green to occ. reddish-purple, 2.5–5 mm, equal; glumes narrow, acute, glabrous or minutely scabrous on the keel toward the tip, nearly equal, lower glume 3-veined, upper glume 1-veined; glumes > florets; lemma 1.5–2 mm, hairy, obtuse to acute. Open to full shade of Island chaparral and coastal sage scrub; <500 m. sChI (Santa Catalina, San Clemente Islands); Baja CA (Guadalupe Island).

Refs. — DISSANTHELIUM CALIFORNICUM (Nutt.) Benth.

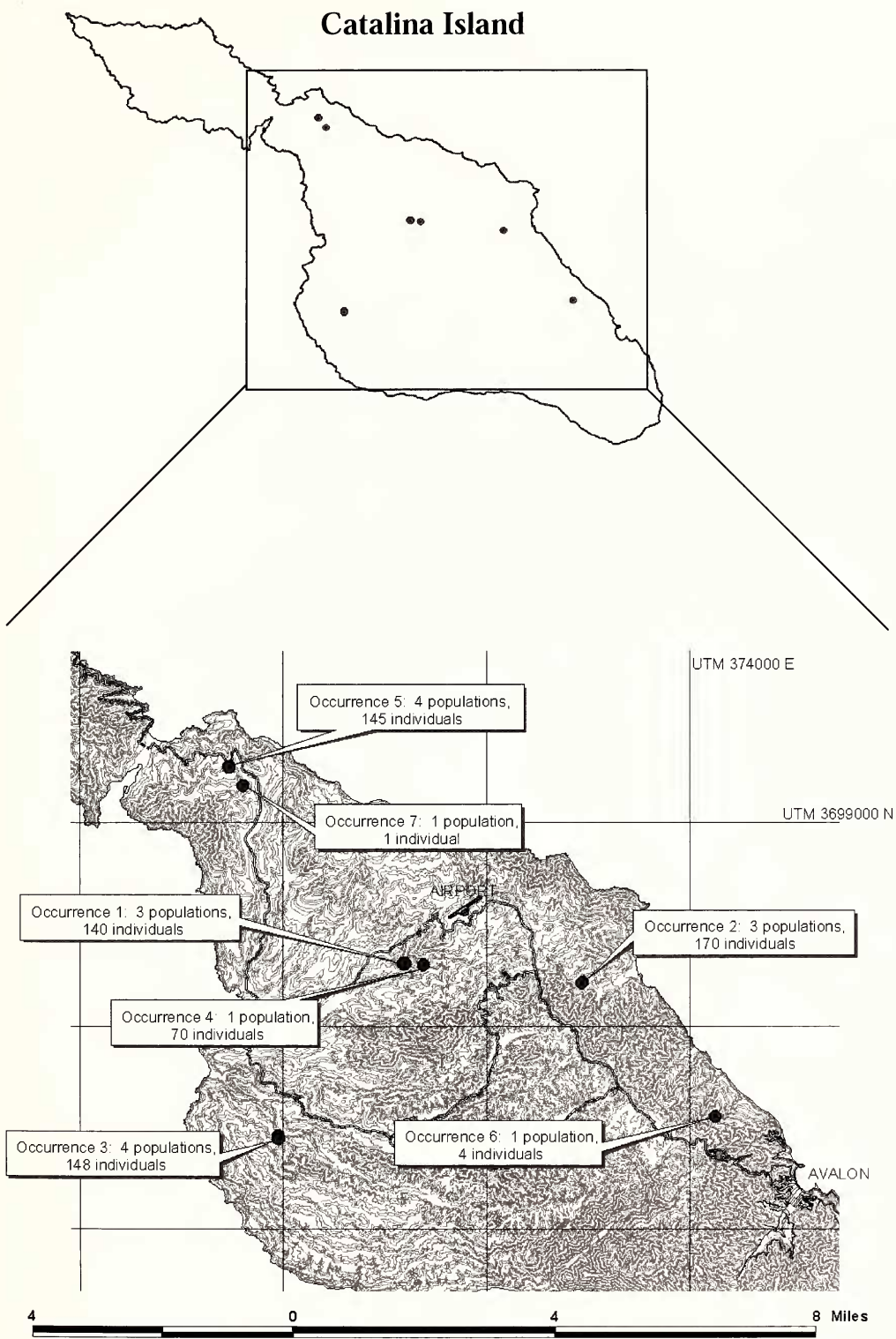


FIG. 2. Map showing all seven occurrences of *D. californicum* found on Catalina Island between the end of March and July of 2005. Numbers of individuals are estimates.

TABLE 1. FLORISTIC DOCUMENTATION OF *D. CALIFORNICUM*. The 1912 date listed in Hickman (1993) appears to be an error, and is revised here as 1903.

Locality	Voucher	Date	Frequency and distribution
USA: CA, Santa Catalina Island	W. Gambel s.n. (GH)	ca. 1841–1845	Unknown
MEXICO: Guadalupe Island.	E. Palmer 96 (NY)	1875	On warm rocky slopes in the middle of the island; not very abundant; very succulent, and the goats are very fond of it (Watson 1876)
Guadalupe	E. Palmer 96 (GH)	1875	
Guadalupe	E. Palmer 96 (CM #268852)	1875	
Guadalupe	E. Palmer 96 (MO)	1875	
San Clemente	B. Trask 324 (US #469621)	1903	“common”
Santa Catalina	J. McCune 1–3 (RSA)	May 2005	Infrequent. Plant found in seven locations on the island (17 populations, 678 individuals)
Santa Catalina	N. Refulio-Rodriguez 238 (RSA)	May 2005	
Santa Catalina	J. McCune 1–3 (SBBG)	May 2005	
Santa Catalina	J. McCune 1–3 Wrigley Memorial Botanical Garden, Avalon, CA.	May 2005	

TABLE 2. SITE CHARACTERISTICS AT *D. CALIFORNICUM* LOCATIONS ON SANTA CATALINA ISLAND. Elevations for all occurrences are approximate. Slope for Occurrence 4 is estimated.

OCC #	UTM	ASP	Slope	Elev.(m)	Habitat	Substrate and associated species
1	366902E 3695747N	87°	5°	260	Island chaparral	Bare ground in part shade of <i>Malacothamnus fasciculatus</i> , with <i>Quercus pacifica</i> , <i>Bromus madritensis</i> , <i>Polypogon interruptus</i> , <i>Chenopodium californicum</i> , <i>Opuntia littoralis</i> .
2	371275E 3695273N	130°	27°	137	Island chaparral/ coastal sage scrub	Leaf litter or soil with large rock outcrops in full or part shade of <i>Q. pacifica</i> or <i>Salvia mellifera</i> , with <i>Brachypodium distachyon</i> , <i>Bromus madritensis</i> , <i>Eucrypta chrysanthemifolia</i> , <i>Melica imperfecta</i> , <i>Opuntia littoralis</i> .
3	363801E 3691475N	340°	34°	182	Island chaparral/ coastal sage scrub	Soil or near large rock outcrops in the open or in part to full shade of <i>Heteromeles arbutifolia</i> , with <i>Salvia mellifera</i> , <i>Polypodium californicum</i> , <i>Trifolium willdenovii</i> , <i>Melica imperfecta</i> , <i>Bromus madritensis</i> , <i>Bromus hordeaceus</i> , <i>Daucus pusillus</i> , <i>Galium nuttallii</i> , <i>Rhus integrifolia</i> , <i>Avena barbata</i> , <i>Vulpia</i> sp.
4	367374E 3695702N	157°	5°	274	Island chaparral/ coastal sage scrub	Moist soil in full or part shade of <i>Rhus integrifolia</i> , with <i>Salvia mellifera</i> , <i>Malacothamnus fasciculatus</i> , <i>Antirrhinum nuttallianum</i> , <i>Phacelia cicutaria</i> , <i>Gnaphalium</i> sp., <i>Solanum</i> sp., <i>Chenopodium californicum</i> , <i>Opuntia littoralis</i> , <i>Polypogon</i> sp., <i>Desmazeria rigida</i> , <i>Brachypodium distachyon</i> , <i>Piptatherum miliaceum</i> .
5	362599E 3700121N	10°	22°	213	Island chaparral	Leaf litter or soil with rock outcrops in full or part shade of <i>Q. pacifica</i> , <i>Rhus integrifolia</i> , or <i>Crossosoma californica</i> , with <i>Bromus madritensis</i> , <i>Gastridium ventricosum</i> , <i>Melica imperfecta</i> .
6	374542E 3691983N	145°	32°	251	Island chaparral	Moist soil, quite bare, in full shade of <i>Q. pacifica</i> , <i>Rhus integrifolia</i> and <i>Cercocarpus betuloides</i> , with <i>Melica imperfecta</i> .
7	362947E 3700121N	0°	26°	290	Island chaparral	Leaf litter in part shade of <i>Q. pacifica</i> , with <i>Opuntia littoralis</i> , <i>Bromus madritensis</i> , <i>Brachypodium distachyon</i> , <i>Sonchus asper</i> .

Swallen & Tovar. *Phytologia* 11: 361–376. 1965.
Benth. in Hook. *Icon. Pl.* III. 4: 56. *pl.* 1375.
1881. Based on the next.
Stenochloa californica Nutt. *Journ. Acad. Phila.*
II. 1:189. 1848. Type from Santa Catalina
Island, *Gambel*.

DISCUSSION

Three factors may have contributed to the rediscovery of *D. californicum* on Catalina Island after having been unrecorded for more than a century. First, it seems likely that *D. californicum*, like many other island plants, has responded to the record rainfall in 2004–2005, making it more abundant and conspicuous than in previous years. Second, the removal of feral goats and pigs has relieved grazing and rooting pressures. Finally, the initiation of our project to characterize the oak communities on Catalina Island brought us to many rarely explored areas.

The island received 68.1 cm of rainfall during the 2004–2005 season (averaged across Avalon, Middle Ranch, Airport-in-the-Sky, and Two Harbors), which was significantly greater than the mean (Conservancy data; 29.8 cm, averaged across four to six sites from 1948–2005) and the highest rainfall recorded to date. This factor likely contributed to the germination, abundance, and robustness of *D. californicum* that year. The response of *D. californicum* populations to rainfall was further indicated by 2006 survey data: after below-average rainfall (24 cm from July 2005 through June 2006), surveys of four out of seven of the known population sites did not reveal any plants.

It is unclear if *D. californicum* has seed that can persist in the soil for years. Generally, grass seed does not persist as long in the soil as seeds of forbs, but annuals are more likely than perennials to form a seed bank (Rice 1989 and references cited therein; Thompson et al. 1998). Although many annual grasses have very short-lived seeds (i.e., 1–3 yr) (Zorner et al. 1984; Roberts 1986; Thompson 1987; Russi et al. 1992; Masin et al. 2006), multiple species of *Poa* (both annual and perennial) have been found to have more persistent seeds (Roberts 1986; Thompson 1987). Results from germination trials by RSA suggest that *D. californicum* seeds do not possess physical dormancy mechanisms, as they obtained 35% germination in 2006 by pre-treating the seeds with only a 24-hour water soak (M. Wall personal communication).

Introduced herbivores may have greatly reduced the abundance and distribution of *D. californicum*. Introduced ungulates have particularly severe impacts on island ecosystems, where endemic plants lack defenses against herbivory, and are a major cause of island extinctions (e.g., Coblentz 1978; Vitousek 1988; Adersen 1989;

Atkinson 1989; Schofield 1989; Bowen and Van Vuren 1997; Oberbauer 2005). Native plants and animals may recover rapidly with the release of this pressure (Wehtje 1994; Laughrin et al. 1994; Chess et al. 2000), depending on environmental factors such as water availability (Donlan et al. 2002). On Guadalupe Island, six plant species presumed extinct and other rare pine seedlings reappeared following goat removal (Krajick 2005).

Feral goats were reported on San Clemente and Catalina Islands by the early 1800s (Dunkle 1950; Raven 1963), and thrived until systematic eradication programs began in the 1970s on San Clemente Island (Moran 1996) and in 1990 on Catalina Island (Schuyler et al. 2002). Currently, few or no goats remain on either island. It is unknown when goats were first introduced on Guadalupe, but the goat population peaked at more than 100,000 in 1870. By 1994, the population had been reduced to 7000 (Moran 1996), and today, nearly all goats have been removed (Island Conservation 2007).

Other introduced animals on Catalina Island that have posed a threat are feral pigs (*Sus scrofa*), mule deer (*Odocoileus hemionus*), and American bison (*Bison bison*). Rooting disturbance by feral pigs decreases plant productivity and may disturb over 65% of the land in areas with high pig densities (Sweitzer and Van Vuren 2002); they have contributed to the extinctions of numerous oceanic island species (Waithman et al. 1999). Although mule deer are primarily browsers, grasses comprise between 21% (December–January) and <1% (June–July) of their diet on Catalina Island, and their population on the 48,000-acre island is estimated at 2341 individuals (range: 1682–3259) (Manuwal and Sweitzer 2007; T. Manuwal, University of North Dakota, unpublished data). Introduced bison on Catalina Island alter plant communities by grazing, foraging, trampling, and wallowing, and have been found to facilitate the dispersal of non-native plants (Sweitzer et al. 2003; Constible et al. 2005). Trampling by bison and deer was found to negatively impact oak seedlings on the island (Manuwal and Sweitzer 2007). Their diet is composed of approximately 84% grasses; they appear to have the positive effect of reducing non-native annual grass cover, although their input of nutrients may also encourage annual grass growth (Sweitzer et al. 2003).

Management of these introduced herbivores is being addressed by the Conservancy. The majority of the feral pigs were eradicated by the end of 2004; there are currently 1–4 animals estimated remaining, and the Conservancy continues its efforts. Bison herds are managed to between 150 and 200 individuals. Mule deer have been harvested almost annually on Santa Catalina Island from 1949 through the present, currently

as part of the Private Lands Management program of the California Department of Fish and Game. Final results from a two-year mule deer study will be submitted by the end of 2007, and management options are under discussion.

With the removal of feral goats from all three islands where *D. californicum* has been known to occur, the remaining threat of largest concern is competition with invasive annual and perennial grasses. These introduced species, including *Bromus* spp., *Avena* spp., *Lolium* spp., and *Vulpia* spp. have been shown to interfere with native shrubs, forbs, and perennial grasses (Young and Evans 1973; Da Silva and Bartolome 1984; Gordon et al. 1989; Danielsen and Halvorson 1991; Eliason and Allen 1997; Dyer and Rice 1999; Hamilton et al. 1999; Brown and Rice 2000; Kolb et al. 2002). Invasive perennial grasses occurring on Catalina such as *Piptatherum miliaceum* (L.) Cosson, *Festuca arundinacea* Shreber and *Phalaris aquatica* L., and other non-grass invasive species are also of concern (Corbin et al. 2004; Bossard et al. 2006). Introduced grasses are listed as associated species at five of the seven occurrences of *D. californicum*. Although invasive annual grasses are too ubiquitous on the island to control except in very targeted areas, the Conservancy has initiated an ambitious Invasive Plant Management Program, targeting 25 species for eradication and five for reduction based on extensive mapping data and ecological impact considerations, and targeting watersheds containing high numbers of rare species and habitats (Knapp and Knapp 2005).

To better understand the status of the species in the wild, we need to know more about its range, frequency and annual variability on the island, its growth requirements, and any additional threats. Studies of seed germination and plant growth requirements are particularly important. The Catalina Island Conservancy continues to monitor known populations of *D. californicum* and survey additional high potential locations; it is our hope that it will regain the 'common' status attributed to it by Trask more than a century ago.

ACKNOWLEDGMENTS

The authors would like to thank Dr. J. Travis Columbus and Nancy Refulio-Rodriguez for their enthusiasm and assistance in researching and reviewing this manuscript, Steve Junak for his expert knowledge and advice, and Lauren K. Danner for her assistance in the field. We also thank Ms. Refulio-Rodriguez for her translation of the abstract to Spanish, as well as John Knapp, John Hunter, and two anonymous reviewers for their helpful suggestions for improving the article.

LITERATURE CITED

- ADSRSEN, H. 1989. The rare plants of the Galapagos Islands and their conservation. *Biological Conservation* 47:49-77.
- ATKINSON, I. 1989. Introduced animals and extinctions. Pp. 54-75 in D. Western and M. C. Pearl (eds.), *Conservation for the 21st century*. Oxford University Press, New York, NY.
- BITTMAN, R. 2001. The California natural diversity database: a natural heritage program for rare species and vegetation. *Fremontia* 29:57-62.
- BOSSARD, C. C., M. BROOKS, J. DI TOMASO, J. RANDALL, C. ROYE, J. SIGG, A. STANTON, AND P. WARNER. 2006. California invasive plant inventory. California Invasive Plant Council, Berkeley, CA.
- BOWEN, L. AND D. VAN VUREN. 1997. Insular endemic plants lack defenses against herbivores. *Conservation Biology* 11:1249-1254.
- BROWN, C. S. AND K. J. RICE. 2000. The mark of Zorro: effects of the exotic annual grass *Vulpia myuros* on California native perennial grasses. *Restoration Ecology* 8:10-17.
- CNPS (CALIFORNIA NATIVE PLANT SOCIETY). 2001. Inventory of rare and endangered plants of California (sixth edition). Rare Plant Scientific Advisory Committee, D. P. Tabor, Convening Editor. California Native Plant Society, Sacramento, CA.
- CHES, K., K. MC EACHERN, AND D. H. WILKEN. 2000. Island jepsonia (*Jepsonia ualvifolia*) demography on Santa Rosa and Santa Cruz Islands, California. Pp. 155-157 in D. R. Browne, K. L. Mitchell, and H. W. Chaney (eds.), *Proceedings of the Fifth California Islands Symposium*. U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region, Camarillo, CA.
- COBLENTZ, B. E. 1978. The effects of feral goats (*Capra hircus*) on island ecosystems. *Biological Conservation* 13:279-286.
- CONSTIBLE, J. M., R. A. SWEITZER, D. H. VAN VUREN, P. T. SCHUYLER, AND D. A. KNAPP. 2005. Dispersal of non-native plants by introduced bison in an island ecosystem. *Biological Invasions* 7: 699-709.
- CORBIN, J. D., M. THOMSEN, J. ALEXANDER, AND C. M. D'ANTONIO. 2004. Out of the frying pan: invasion of exotic perennial grasses in coastal prairies (Abstract). Pp. 27-28 in C. Piroosko (ed.), *Proceedings of the California Invasive Plant Council Symposium*, Vol. 8. California Invasive Plant Council, Berkeley, CA.
- DANIELSEN, K. C. AND W. L. HALVORSON. 1991. Valley oak seedling growth associated with selected grass species. Pp. 9-13 in *Proceedings of the symposium on oak woodlands and hardwood rangeland management*. General Technical Report PSW-12, U.S. Forest Service, Albany, CA.
- DA SILVA, P. G. AND J. W. BARTOLOME. 1984. Interaction between a shrub, *Baccharis pilularis* subsp. *consanguinea* (Asteraceae) and an annual grass, *Bromus mollis* (Poaceae), in coastal California. *Madroño* 31:93-101.
- DONLAN, C. J., B. R. TERSHY, AND D. A. CROLL. 2002. Islands and introduced herbivores: Conservation action as ecosystem experimentation. *Journal of Applied Ecology* 39:235-246.
- DUNKLE, M. B. 1950. Plant ecology of the Channel Islands of California. University of Southern California Press, Los Angeles, CA.
- DYER, A. R. AND K. J. RICE. 1999. Effects of competition on resource availability and growth of a California bunchgrass. *Ecology* 80:2697-2710.

- EASTWOOD, A. 1941. The islands of southern California and a list of the recorded plants. Leaflets of Western Botany 3:54–78.
- ELIASON, S. A. AND E. B. ALLEN. 1997. Exotic grass competition in suppressing native shrubland re-establishment. *Restoration Ecology* 5:245–255.
- GORDON, D., J. M. WELKER, J. W. MENKE, AND K. J. RICE. 1989. Competition for soil water between annual plants and blue oak (*Quercus douglasii*) seedlings. *Oecologia* 79:533–41.
- GRAUSTEIN, J. E. 1967. Thomas Nuttall, Naturalist: Explorations in America 1808–1841. Harvard University Press, Cambridge, MA.
- HAMILTON, J. G., C. HOLZAPFEL, AND B. E. MAHALL. 1999. Coexistence and interference between a native perennial grass and non-native annual grasses in California. *Oecologia* 121:518–526.
- HITCHCOCK, A. S. 1923. *Dissanthelium*, an American genus of grasses. *Journal of the Washington Academy of Sciences* 13:223–225.
- HOOKER, J. D. (ed.). 1881. Hooker's *Icones Plantarum*: or, figures, with descriptive characters and remarks, of new and rare plants, selected from the Kew herbarium. Third Series. Vol. XIV, Part III. Williams and Norgate, London.
- ISLAND CONSERVATION. 2007. Guadalupe Island restoration project. Available at: <http://www.islandconservation.org/guadalupe.html>
- JEPSON, W. L. 1912. A flora of California. Volume 1, Parts 1–7. University of California, Berkeley, CA.
- JERCINOVIC, G. 2004. William Gambel: New Mexico plant specimens. *The New Mexico Botanist* 30:2–4.
- KNAPP, D. A. AND J. J. KNAPP. 2005. Ecosystem protection through watershed-level prioritization on Catalina Island. Pp. 39–46 in G. Skurka (ed.), *Proceedings of the California Invasive Plant Council Symposium*, Vol. 9. California Invasive Plant Council, Berkeley, CA.
- KOLB, A. P., A. D. ENTERS, AND C. HOLZAPFEL. 2002. Patterns of invasion within a grassland community. *Journal of Ecology* 90:871–881.
- KRAJICK, K. 2005. Winning the war against island invaders. *Science* 310:1410–1413.
- LAUGHRIN, L., M. CARROLL, A. BROMFIELD, AND J. CARROLL. 1994. Trends in vegetation changes with removal of feral animal grazing pressures on Santa Catalina Island. Pp. 523–530 in W. L. Halvorson and G. J. Maender (eds.), *The fourth California Islands symposium: Update on the status of resources*. Santa Barbara Museum of Natural History, Santa Barbara, CA.
- MANUWAL, T. AND R. SWEITZER. 2007. Advance report, Catalina Island mule deer project: Implications of introduced large ungulates on island scrub oak habitats on Santa Catalina Island, California. Unpublished preliminary report prepared for Catalina Island Conservancy, Avalon, CA.
- MASIN, R., M. C. ZUIN, S. OTTO, AND G. ZANIN. 2006. Seed longevity and dormancy of four summer annual grass weeds in turf. *Weed Research* 46:362–370.
- MCKELVEY, S. D. 1955. Botanical exploration of the trans-Mississippi West 1790–1850. Arnold Arboretum of Harvard University, Jamaica Plain, MA.
- MILLSPAUGH, C. F. AND L. W. NUTTALL. 1923. Flora of Santa Catalina Island (California). Field Museum of Natural History, Chicago, IL.
- MORAN, R. 1996. The flora of Guadalupe Island, Mexico. California Academy of Sciences, San Francisco, CA.
- NICORA, E. G. 1973. Novedades agrostológicas patagónicas. *Darwiniana* 18(1–2):80–106.
- NUTTALL, T. 1848. Descriptions of plants collected by William Gambel, M.D., in the Rocky Mountains and Upper California. *Journal of the Academy of Natural Sciences of Philadelphia* vol. 1 second series:149–189.
- OVERBAUER, T. 2005. A comparison of estimated historic and current vegetation community structure on Guadalupe Island, Mexico. Pp. 143–151 in D. K. Garcelon and C. A. Schwemm (eds.), *Proceedings of the Sixth California Islands Symposium*. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata.
- RAVEN, P. H. 1963. A flora of San Clemente Island, California. *Aliso* 5(3):289–347.
- REFULIO-RODRIGUEZ, N. F. 2007. Systematics of *Dissanthelium* Trin. (Poaceae: Pooideae). Ph.D. dissertation. Claremont Graduate University, Claremont, CA.
- RICE, K. 1989. Impacts of seed banks on grassland community structure and population dynamics. Pp. 211–230 in M. A. Leck, V. T. Parker, and R. L. Simpson (eds.), *Ecology of soil seed banks*. Academic Press, San Diego, CA.
- ROBERTS, H. A. 1986. Persistence of seeds of some grass species in cultivated soil. *Grass and Forage Science* 41(3):273–276.
- ROSS, T. S., S. BOYD, AND S. JUNAK. 1997. Additions to the vascular flora of San Clemente Island, Los Angeles County, California, with notes on clarifications and deletions. *Aliso* 15(1):27–40.
- RUSSI, L., P. S. COCKS, AND E. H. ROBERTS. 1992. Seed bank dynamics in a Mediterranean grassland. *Journal of Applied Ecology* 29:763–771.
- SCHOFIELD, E. K. 1989. Effects of introduced plants and animals on island vegetation: Examples from the Galapagos Archipelago. *Conservation Biology* 3:227–238.
- SCHUYLER, P. T., D. GARCELON, AND S. ESCOVER. 2002. Control of feral goats (*Capra hircus*) on Santa Catalina Island, California, USA. p. 412 in C. R. Veitch and M. N. Clout (eds.), *Turning the tide: The eradication of invasive species*. *Proceedings of the international conference on eradication of island invasives*, February 2001. Occasional Paper of the IUCN Species Survival Commission No. 27. IUCN, Gland, Switzerland and Cambridge, UK.
- SMITH, J. P. 1993. Poaceae. Pp. 1218–1303 in J. C. Hickman (ed.), *The Jepson manual: higher plants of California*. University of California Press, Berkeley, CA.
- SORENG, R. J. 1998. An infrageneric classification for *Poa* in North America, and other notes on sections, species, and subspecies of *Poa*, *Puccinellia*, and *Dissanthelium* (Poaceae). *Novon* 8:187–202.
- , P. M. PETERSON, G. DAVIDSE, E. J. JUDZIEWICZ, F. O. ZULOAGA, T. S. FILGUEIRAS, AND O. MORRONE. 2003. Catalogue of New World grasses (Poaceae): IV. Subfamily Pooideae. *Contr. U.S. Natl. Herb.* 48:1–730. Available at: <http://mobot.org/W3T/Search/nwgc.html>
- SWALLEN, J. R. AND O. TOVAR. 1965. The grass genus *Dissanthelium*. *Phytologia* 11:361–376.

- SWEITZER, R. A. AND D. H. VAN VUREN. 2002. Rooting and foraging effects of wild pigs on tree regeneration and acorn survival in California's oak woodland ecosystems. Pp. 219–231 in R. B. Standiford, D. McCreary, and K. L. Purcell (tech. cords.) (eds.), Proceedings of the fifth symposium on oak woodlands: Oaks in California's changing landscape. General Technical Report PSW-GTR-184. Pacific Southwest Research Station, U.S. Forest Service, Albany, CA.
- , J. CONSTIBLE, AND D. H. VAN VUREN. 2003. Population ecology and ecological effects of bison on Santa Catalina Island, California. Unpublished report prepared for Santa Catalina Island Conservancy, Avalon, CA.
- THOMPSON, K. 1987. Seeds and seed banks. *New Phytologist* 106:23–34.
- , J. P. BAKKER, R. M. BEKKER, AND J. G. HODGSON. 1998. Ecological correlates of seed persistence in soil in the north-west European flora. *Journal of Ecology* 86:163–169.
- THORNE, R. F. 1967. A flora of Santa Catalina Island, California. *Aliso* 6:1–77.
- . 1969. A supplement to the floras of Santa Catalina and San Clemente Islands, Los Angeles County, California. *Aliso* 7:73–83.
- TOVAR, O. 1985. Ocho especies nuevas de Gramineas del Perú. *Publicaciones del Museo de Historia Natural "Javier Prado"*. Serie B. *Botánica* 33:1–16.
- VITOUSEK, P. M. 1988. Diversity and biological invasions of oceanic islands. Pp. 181–189 in E. O. Wilson (ed.), *Biodiversity*. World Resources Institute, Washington, D.C.
- WAITHMAN, J. D., R. A. SWEITZER, D. VAN VUREN, J. D. DREW, A. J. BRINKHAUS, I. A. GARDNER, AND W. M. BOYCE. 1999. Range expansion, population sizes, and management of wild pigs in California. *Journal of Wildlife Management* 63:298–308.
- WALLACE, G. W. 1985. Vascular plants of the Channel Islands of southern California and Guadalupe Island, Baja California, Mexico. *Contributions in Science*, Number 365. Natural History Museum of Los Angeles County, Los Angeles, CA.
- WATSON, S. 1876. *Botanical Contributions*. Proceedings of the American Academy of Arts and Sciences 11:105–148.
- WEHTJE, W. 1994. Response of a Bishop pine (*Pinus muricata*) population to removal of feral sheep on Santa Cruz Island, California. Pp. 331–340 in W. L. Halvorson and G. J. Maender (eds.), *The fourth California Islands symposium: Update on the status of resources*. Santa Barbara Museum of Natural History, Santa Barbara, CA.
- YOUNG, J. A. AND R. A. EVANS. 1973. Downy brome – intruder in the plant succession of big sagebrush communities in the Great Basin. *Journal of Range Management* 26(6):410–415.
- ZORNER, P. S., R. L. ZIMDAHL, AND E. E. SCHWEIZER. 1984. Sources of viable seed loss in buried dormant and non-dormant populations of wild oat (*Avena fatua* L.) seed in Colorado. *Weed Research* 24(2):143–150.